Abstract—This paper reports results of experiments on the application of solar regenerated desiccant for dehumidification of the ventilation air together with application of radiant cooling for thermal comfort. A set of solid desiccant (silica gel) packed beds were exposed to solar radiation during daytime. The packed beds were attached to the inlet of the ventilation duct of an experimental room in the Energy Park at AIT to dehumidify the ventilation air during night time. This dehumidification set up was used in conjunction with the use of panels supplied with cool water for cooling to achieve thermal comfort. The use of solid desiccant pack beds reduced moisture in the ventilation air resulting in the reduction of humidity in the room. This allows cold water of a lower temperature to be used in the radiant panel, thus increasing the capacity of the panel. At lower temperatures, the capacity for achieving thermal comfort is enhanced. The cooling panel was able to reduce sensible heat of air while it also reduced the temperatures of other surfaces in the room through thermal radiation. This combination enables quiet quality thermal comfort to be achieved. The well-known TRNSYS program was used to simulate application of this combination. Results of simulation agreed well with results from experiment.

Keywords — Thermal comfort, Radiant cooling, Desiccant, Building energy simulation.

1. INTRODUCTION

Currently most offices in Thailand are air-conditioned by forced-air systems and cooling is exclusively based on convection. Cooling of buildings equipped with conventional systems significantly contributes to the electrical energy consumption and to the peak-power demand.

Radiant cooling is an option since it has potential for both energy conservation and peak power saving. It also provides equal levels of comfort when compared to conventional systems. Radiant cooling has been refined and used successfully in Europe for more than 20 years [1]. With radiant cooling, heat is transferred between room space and panels through a temperature differential. The cool radiant panels on the ceiling receive heat through a combination of radiation and convection. Radiative heat transfer occurs through net emission of electromagnetic waves from the warm occupants and their surroundings to the cool ceiling. On the other hand, convection first cools room air in contact with the cool ceiling, creating convection currents within the space. Surfaces in the space then transfer heat directly to the cool ceiling by thermal radiation and to the cooled air through convection.

Apart from achieving quiet thermal comfort, the combination of solar regenerated desiccant dehumidification and radiant cooling panels supplied with cool water also possesses good potential for significant energy conservation. This could come about from the use of cool water obtained from passive means.

2. BRIEF REVIEW OF A SOLID DESSICANT DEHUMIDIFICATION AND RADIANT COOLING

To improve radiant cooling performance, a dehumidification system offers potential. A ventilation system can be used to provide room air with dew point below or at panel supply water temperature. A desiccant cooling system could reduce humidity of the air by removing moisture from the air. Lu and Yan [2], presented development and experimental validation of a full-scale solar desiccant enhanced radiative cooling system. The solid desiccant used in the system was silica gel. Basically, during a 24 h cycle, the subsystem of solid desiccant undergoes a regeneration process when it is exposed to the sunlight and undergoes a dehumidification process when it is covered by shadow or at night. Thoruwa et al. [3, 4], presented a prototype that used solid desiccant (bentonite CaCl2) for dehumidified air at night regenerated by solar energy during the day. Techajunta et al. [5], presented an indoor and analytical study to evaluate the performance of a desiccant system that uses silica gel as desiccant. The experimental data and the calculations show that it should be possible to operate this system in tropical humid climates using the regeneration process in the day by solar radiation and the air dehumidification at night time. Many studies have emphasized hybrid systems. Busweiler [6], demonstrated that the cooled ceiling and desiccant cooling helped to ensure good thermal comfort, save energy, and reduce peak electric consumption. The result of the first year of the system’s operation in a Bremen hotel revealed that the two systems are a good and practical combination in rooms. Niu et al. [7], presented hourly calculation of sensible and latent loads through a building energy simulation code ACCURACY and of the moisture balance in the room for a chilled-ceiling with desiccant cooling application. The results show that the system’s primary energy consumption could amount to 44 % in comparison with a conventional air-conditioning system. Ameen et al. [8], studied a silica gel desiccant-based air dehumidifier and chilled ceiling in a climate chamber. Such a system is a very promising proposition to reach thermal comfort with respect to energy savings where the chiller capacity can be downsized by 15 % as in this study.

3. EXPERIMENTAL ROOM AND MEASUREMENT SETUP

3.1 The Experimental Room

This room has been constructed for physical experiment on energy conservation in buildings. It is a single story building that measures 4 m wide, 4 m long, and 3 m high with a flat roof. The height of the ceiling is 2.5 m, so the height of the ceiling plenum is 0.5 m. Fiberglass insulation and radiant barrier have been placed above the ceiling to reduce heat gain from roof. Moisture blocking membranes are placed on the interior layer of opaque walls during construction to reduce moisture entry and air leakage. The wall on the east façade comprises six different
opaque sections installed for demonstration of dynamic heat gain through sections of wall of different thermal resistances and thermal capacitances. Four different glazing types, are double glassing, reflective glassing, tinted glassing, and clear glass with film, cover the window on the western façade that takes up 55% of area of the façade. The north, west and south facades comprise 8 cm brick walls plastered with cement mortar on both surfaces. Fiber glass insulation and gypsum board form additional interior layers for these two walls. Most of the wall sections on the east façade do not have insulation so this wall possesses inferior average thermal resistance in comparison to opaque walls in other facades. The floor comprises 15 cm concrete and gypsum board with vinyl cover on the interior opaque walls in other facades. The ceiling comprises gypsum board with fiber glass insulation above on it.

Because of excessive heat gain from solar radiation on the western façade, an exterior board was placed at 10 cm from the window glazing that allowed air to flow through but totally blocked sun and sky radiation entering the window for all experiments described in this chapter. Even for the experiments carried out during night time only, heat gained from solar radiation entering on the western façade during afternoon accumulated in the building masses and persisted until late in the night. This was severe during the hot and dry period and prompted us to use the shading board.

**Fig.1. A Photograph and a Diagram of the Experimental Room**

**Radiant Cooling Panels** The metallic cooling panels are made of either copper or aluminum. The materials used have a fast thermal response. The thermal insulation is placed on top or beside of the panel in order to reduce the heat loss, to allow a privileged downward transfer, and to improve the acoustics of the room. A 5.75 m² of the radiant cooling panel formed from two panels of 8 passes serpentine copper coil bonded by lead to a copper sheet has been installed on the ceiling. Another 1.75 m² of radiant cooling panels was installed on the opaque section beneath the window on the western façade. This second panel is formed from two panels each constructed from parallel water tubes connected in parallel. Fig.1 shows a photograph and a diagram of the experimental room. The diagram in Fig. 1b illustrates the position of the cooling panels, one on the ceiling and one on the opaque wall below the glazed window. These two panels were installed prior to the present rounds of experiments. The diagram in Fig. 1b also illustrates the position of the boards placed to shade solar radiation.

**Cooling Water Supply and Its Control System** Cooling water that flows to the cooling panels is supplied from a tank and is circulated by a pump. Fig. 2 shows a diagram of the cooling water supply and control system. Chilled water from AIT central chilled water plant is supplied into a mixing tank through a solenoid valve. A controller turns the solenoid valve on or off based on signal from a temperature sensor placed in the cooling water loop.

The pump and the solenoid valve are operated simultaneously by a controller using signal from an air temperature sensor T1, located in the room. When temperature of the air in the room rises above a set value, the pump and the solenoid valve in the cooling water loop operates. If there is sufficient load on the cooling panels, the temperature in the cooling water loop will rise beyond the water temperature set point. If this happens, the chilled water controller will open the solenoid valve to allow chilled water from the AIT central chilled water supply system, which is at a higher pressure, to flow into the mixing tank. This will reduce the temperature of the water in the cooling water supply loop.

**Dehumidifying Ventilation Air System** Ventilation air is still supplied into the experimental room by a fan. However, first the fresh ventilation air flows through a solid desiccant system and then passes to the inlet port. The details of the solid desiccant system are presented in a series of figures. Figure 3a shows a fabricated air duct with 3 glass sides and a bottom side made of an aluminium sheet. The reason for the glass is to expose a set of six Integrated Desiccant Collectors (IDCs) to direct sunlight. Figure 3b shows ten meshes of thin brass cylinders (diameter 0.015 m) that are filled with spherical silica gel particles 3.0 mm in diameter. The frame for the IDCs is fabricated from aluminium material. Each pack contains approximately 300 grams mass of the dry silica gel out of a total weight of 650 grams for each IDC. Air pressure drop between IDCs is reduced by 0.003 m gaps between the thin brass cylinders.

**3.2 Measurement Setup**

**Temperature of Surfaces** The temperature of each of the 22 distinct surfaces in the room was measured by a thermocouple, type T. Each of the six wall sections on the east façade constitutes a distinct surface, for example, four thermocouples are placed on the surface of the cooling panel on the ceiling and two are placed on the wall cooling panel. The average of four point temperatures on panel means the temperature of cooling panel on ceiling. The average of two point temperatures on panel means the temperature of cooling panel at wall.

**Air Temperature and Relative Humidities** The temperature and relative humidity of the room air, of the air at the inlet
and outlet of the cooling coil of the fan coil unit, and of the ventilation air (at the inlet port in the room) are measured by electronic sensors. In addition, three thermocouple sensors are hung beneath the ceiling cooling panel at distances of 0.2, 1.25 and 1.75 m from the floor to measure air temperature beneath the panel and two sensors of relative humidity transmitter at distances of 0.2 m and 1.75 m from the floor. The average of the temperature at the three points is taken as the room air temperature. The average of the humidity at the two points (0.2 m and 1.75 m) is taken as the humidity of room air.

**Heat Flows** The heat flows through all opaque walls and cooling panels are measured by heat flux sensors attached to the surfaces of the wall sections and the cooling panels.

**Water Flows** The rate of water flows (m$^3$s$^{-1}$) at the inlet of each cooling panel and at the cooling coil of the fan coil unit are measured by three rotameters equipped with signal transmitters.

**Air Flow** The rate of airflow of the ventilation air at the inlet port and of the circulation air at the inlet and outlet of the cooling coil of the fan-coil unit are measured manually by a hot–wire anemometer and are recorded manually.

**Data Recording** The data from the sensors are transmitted to the respective signal conversion panels and stored in a personal computer. The data are recorded at every minute. A software was used to process the data that allows graphs of data values to be viewed in real time.

$$T_{rai}, RH_{rai} \quad \text{of inlet process air}$$

$$T_{rao}, RH_{rao} \quad \text{of outlet process air}$$

**4. TRNSYS PROGRAM AND COMPUTATION OF COMFORT INDICES**

The TRNSYS program was employed to simulate operation of the cooling panels and the fan coil under the conditions of the experiments and under other conditions in this study. Release 15 of this program, so-called TRNSYS 15 [9], now incorporates an “active wall” component that allows simulation of operation of cooling panel. It also performs computation of comfort indices.

**4.1 TRNSYS Program**

TRNSYS is a transient system simulation program with a modular structure. This program was used to simulate the radiant cooling system and ventilation system in the experimental building.

**4.2 Computation of Comfort Indices**

TRNSYS adopts International Standards Organization’s procedure for computation of predicted mean vote or PMV for moderate thermal environment as given in standards document EN ISO 7730-1995 (BS EN ISO, 1995) [10]. This standard in turn adopts Fanger’s recommended equations for calculation of PMV based on four given physical variables of dry–bulb temperature, relative humidity, mean radiant temperature, and air speed. Two personal variables of clothing insulation value and metabolic rate are also required for PMV evaluation.

The multi-zone building module calculates values of three physical variables in a simulation run. The air speed, the fourth variable, was entered as 0.15 m$^{-1}$ for TRNSYS simulation as well as for manual calculation of PMV of a condition using measured values. With user-input values of the two personal variables, the module produces a value of PMV for the environment in the zone at each time step.

TRNSYS permits the calculation of view factor between the flat surfaces in a room, for the purpose of calculating the radiant heat exchange (Solaini et al. [11]). These algorithms cannot be utilized for evaluating the radiant exchange between a human being and the surfaces of the room (Solaini et al. [11]).

**4.3 The Thermal Sensation Prediction Tool for Calculation of Comfort Parameters**

The thermal sensation prediction tool was developed by Fountain and Huizenga [12], as a part of ASHRAE Research Project 781-RP. In their work, they described the components of the thermal sensation models and presented the examples of how the tool could be used in practice.

**Mean Radiant Temperature** This is one of the four physical variables required for PMV evaluation. It generally distinguished three positions, standing, sitting and lying down. The multi-zone building module of TRNSYS also gives values of temperature of each surface in the model room. For this study, a person in the lying position was represented by a rectangular box. The study in this chapter adopts a procedure used in reference (Nagano and Mochida [13]) to calculate the mean radiant temperature appropriate for such an object. First, the mean radiant temperature sensed by the rectangular box where all surfaces are highly absorptive is calculated from:

$$T_m^w = \frac{\sum_j A_j T_{s,j}}{\sum_j A_j}$$

Where $T_j$ is the temperature of a surrounding surface j. The mean radiant temperature sensed by the rectangular box is then taken as the area weighted average of the mean radiant temperature sensed by each surface,

$$T_m = \frac{\sum_i A_i T_{m,i}}{\sum_i A_i}$$

The mean radiant temperature, $T_m$, obtained using this representation was used together with values of other physical variables and given values of personal variables to calculate PMV using the computer code distributed by ASHRAE (Fountain and Huizenga [14]). The experiments in this study utilized the rectangular box to represent a reclining human body in one configuration. In the configuration, a reduced volume of the room was utilized. The dimensions of the rectangular box were: length 1.8 m, width 0.4 m, and thickness 0.2 m. The configuration was devised to reduce the load on the cooling panel. A mosquito net was hung from the ceiling to enclose the 5.76 m$^2$ of cooling panel on the ceiling and the platform that supports the rectangular box as shown in Fig. 4. The space within the net enclosed the cooling ceiling panel and the platform representing a bed. This configuration of mosquito net use to prevent insect entry into the confined space around the bed while resting and sleeping as practiced in traditional Thai houses and is still in use. In our situation, the mosquito net helped reduce the ceiling panel load and confined the intended
cooling load of human beings to the position where radiant cooling from the ceiling panel became more effective. Air movement through the net was slightly retarded, so connective heat gain from the exterior space to the space inside the net was also reduced. There were four surfaces on the sides and one on top of the rectangular box. The view factor from the upper surface of the rectangular box to the cooling panel remained the same at 0.40. With the use of rectangular box to represent a human body in the reclining position, value of mean radiant temperature calculated using Equation 1a and 1b were slightly lower than those that would result from other configuration. This result is also noted in Nagano and Mochida [13].

Fig. 4. Configuration of the Rectangular Box on a Platform and the Ceiling Panel in Enclosed by a Mosquito Net

4.4 Weather Data for TRNSYS

Weather data inputs to the program came from the AIT station. Simulations reported in this study employ these data and the time step used was fifteen minutes.

5. RESULTS OF EXPERIMENTS AND TRNSYS SIMULATION

An experiment was conducted from April 29th to May 1st, 2004 by using one set of dehumidifier comprising six IDCs. The experimental procedure is described in Table 1. The procedure for this experiment during a 24 h period was divided into three periods. Period one covers from 20:00 to 6:00 of the following day, during which the single set of dehumidifier was used and radiative cooling processes took place. Period two covers two intervals from 6:00 to 10:00 and 15:00 to 20:00, during which all IDCs were idle, i.e., no process occurred during this period. Period three is from 10:00 to 15:00, during which the set of IDCs were exposed to sunlight and underwent the regeneration process. The three experimental periods are similar to those in Lu and Yan [2]. After the experiment was completed, the ventilation air was found to be much drier so the duration of the experiment was increased. For this, two sets of six IDCs were investigated from July 31st until August 3rd. The results of this dehumidifying ventilation air system combined with the cooling panels will be discussed for the period August 2nd - 3rd, 2004.

5.1 Night Time Application Using One Cooling Panel With One Set of Six IDCs to Dehumidify Ventilation Air in a Limited Space

Experiments were conducted using the ceiling radiant panel with an area of 5.75 m² alone as in the configuration in Fig. 4. The experimental days took place in the hot and dry period, but with even warmer temperatures. Apart from the data acquisition equipment in the room, two 40-Watt electric lamps were employed in the mosquito net to represent the human load.

TRNSYS Simulation External environmental data for 20:00 hours from meteorological station were used. Other relevant data are summarized in Table 2. The space in the mosquito net was modeled as a zone within the room. Because there was no latent load in the room, and because of dryer ventilation air due to the desiccant system, there was no condensation of moisture on the panels.

Results of Experiments and of Simulation of Radiant Cooling

System Fig. 5 shows graphs for air temperature, $T_{ave}$, within the confined space enclosed by the mosquito net, air temperature in the room, $T_{ave}$, ambient temperature, $T_{ave}$, and temperature of the surface of the panel, $T_{ave}$. The ambient air temperature fell from 31 and 32 ℃ to 26.5 and 28.5 ℃ from 20:00 to 06:00 on the first and second day, respectively. Also relative humidity of ambient air rose from 55 to 90 % during the same times on both days.

Table 1 Procedure of the experiments

<table>
<thead>
<tr>
<th>Date (Time)</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>29 April 04 (19:45-20:00) Preparation for adsorption process</td>
<td>• Take IDCs out of the resealable plastic bags • Weigh each IDC, then place it in the ventilation duct and seal the edge of open side duct with silicone to reduce air leakage</td>
</tr>
<tr>
<td>29 - 30 April 04 (20:00-06:00) Period 1 Adsorption process</td>
<td>• Start the process</td>
</tr>
<tr>
<td>30 April 04 (06:00-09:45) Period 1 First idle interval / Waiting for regeneration process</td>
<td>• Weigh each IDC again to collect the new weight • Put them into the resealable plastic bags</td>
</tr>
<tr>
<td>30 April 04 (09:45-10:00) Preparation for regeneration process</td>
<td>• Start the regeneration process</td>
</tr>
<tr>
<td>30 April 04 (10:00-15:00) Period 2 Regeneration process</td>
<td>• Use small DC fan to force ambient air through the silica gel heated by solar radiation to remove moisture</td>
</tr>
<tr>
<td>30 April 04 (15:00-19:45) Period 2 Second idle interval</td>
<td>• Weigh each IDC again to find the new decreased moisture weight • Put the IDCs in resealable plastic bags for the next night’s use</td>
</tr>
</tbody>
</table>

Table 2 Data of the room, cooling panels, and load during 20:00 - 06:00 of 29 April - 01 May 2004

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Values for 29-30 April 04</th>
<th>Values for 30-01 May 04</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial temperature</td>
<td>31</td>
<td>32.5</td>
</tr>
<tr>
<td>Flow rate of cooling water into ceiling panel (kg/h)</td>
<td>422</td>
<td>436</td>
</tr>
<tr>
<td>Set temperature of cooling water</td>
<td>23</td>
<td>22.5</td>
</tr>
<tr>
<td>Load within the mosquito net</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiative (W)</td>
<td>56.1</td>
<td>56.1</td>
</tr>
<tr>
<td>Convective (W)</td>
<td>23.9</td>
<td>23.9</td>
</tr>
<tr>
<td>Values of personal variables</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metabolic rate (Met)</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Clothing insulation (clo)</td>
<td>0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

We use additional suffix to the subscript $m$ to indicate that a given variable represent measured value and suffix $T$ to indicate a TRNSYS calculated value. For example, $T_{ave}$.
Temperature of the ceiling panel and the interior was limited. Although the air could flow through the net, this difference results from the use of the mosquito net. However, the air exchange between the exterior and interior was limited.

The temperature for both nights was different due to the use of a cooling ceiling panel in the mosquito net. The air temperature in the confined space was higher than the room air temperature for both nights. This difference results from the use of the mosquito net. Although the air could flow through the net, in the absence of wind pressure, air exchange between the exterior and interior was limited.

**Results of Experiment on Adsorption of Moisture by Solid Desiccant**

For the experiments on both nights, the ventilation air was dehumidified by the solid desiccant. The total six packed of dry silica gel weight was 1843 and 1893 g. Then after the adsorption, the weight of total six silica gel packs was increased by 373 and 330 g on the first and the second night, respectively. The increased weight is approximately 20 and 17% of the original dry weight which is equivalent to a moisture adsorption rate of 5.4 and 5.0 g/h’pack \(^{-1}\) for the first and the second night, respectively.

The fresh ventilation air flowed through the desiccant packed beds with a velocity of 35 kg/h’ (0.008 m/s \(^{-1}\)). The outlet process air temperature was higher than the inlet process air temperature due to exothermic heat released from the silica gel. Also, the humidity of outlet process air was lower than the inlet process air due to the moisture adsorbed by the silica gel. The effect was the same and characteristic for both nights as shown in Fig. 7 (a and b).

Fig. 8 (a and b) shows the calculated adsorption rate of the solid desiccant from measured values of ventilation air for both nights. These values are calculated from differences between inlet and outlet humidity ratios for ventilation air multiplied by the air mass flow rates. The maximum values of adsorption rate were approximately 70 and 60 g/h’ on the two nights, respectively. The result of adsorption rate agree well with the result from Techajunta et al. [5], which was around 60 g/h’ at the beginning, falling after 2 hours. All values of adsorption rate were less than zero which means the moisture content of ventilation air was being removed. As they were lower than zero, one set of six IDCs has enough capacity for this operation.

**Results of Experiment on Regeneration of Solid Desiccant**

On April 30th and May 1st, 2004 (06:00 – 10:00), all IDCs were
packed in resealable plastic bags. Nearly all the IDC in these bags had no moisture weight gain, but for some whose weights changed in the range of ±0.5 g tolerance weight. Afterwards, the IDCs were brought out for exposure to sunlight to dry the moisture in the regeneration period from 10:00 to 15:00 (5 h), which is the period of highest solar radiation in the day. The same process was followed on both days. Regeneration air which is the period of highest solar radiation in the day. The moisture in the regeneration period from 10:00 to 15:00 (5 h), IDCs were brought out for exposure to sunlight to dry the changed in the range of ±0.5 g tolerance weight. Afterwards, the bags had no moisture weight gain, but for some whose weights packed in resealable plastic bags. Nearly all the IDC in these packs were 1892.5 and 1991 g, respectively. The total weight of six silica gel packs was decreased by 323 and 233 g for the first and the second day, respectively. The decreased weight is approximately 14.6 and 10.5 % of the original wet weight which is equivalent to a moisture regeneration rate of 10.8 and 7.8 gh⁻¹pack⁻¹ for the first and the second day, respectively.

The total solar heat source was 10.38 and 8.71 MJm⁻² day on the two days, respectively. The measured values of mean silica gel surface temperature were 42.3 and 40.8 °C. The average moisture regeneration efficiency of the IDCs was approximately 0.312 and 0.268 for the first and second day. The assumption enthalpy of water vapour at the silica gel surface temperature at 40 °C was 2,407 kJkg⁻¹. The moisture regeneration efficiency can be calculated from the total weight change of the six packs of silica gel multiplied by the enthalpy of the water vapour at 40 °C and then divided by the solar energy falling on the total six face areas of IDC (0.24 m²).

The regenerating air flowed through the desiccant packed beds with a velocity of 35 and 45 kgm⁻¹ by air forced from two small DC axial fans on the first and second day respectively. The outlet air from duct had high humidity due to the moisture released by the solid desiccant. The profiles of temperature and humidity levels of the regenerating air are shown in Fig. 9.

The total six packs of wet silica gel weighed 2215.5 and 2224 g, respectively. After regeneration, the weights of the six packs of dried silica gel were 1892.5 and 1991 g, respectively, on the first and second days. The total weight of six silica gel packs was decreased by 323 and 233 g for the first and the second day, respectively. The decreased weight is approximately 14.6 and 10.5 % of the original wet weight which is equivalent to a moisture regeneration rate of 10.8 and 7.8 gh⁻¹pack⁻¹ for the first and the second day, respectively.

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experiment data of Techajunta et al. [5], that the regeneration rate obtained from about 100 gh\textsuperscript{-1} kg\textsuperscript{-1} silica gel with insolation 700 Wm\textsuperscript{-2} and constant 3 kgh\textsuperscript{-1} of air flow rate. So it means the lower rate of regeneration may come from the air flow rate higher than the 3 kgh\textsuperscript{-1}.

5.2 Night Time Application Using One Cooling Panel With Two Sets of Six IDCs to Dehumidify Ventilation Air in a Limited Space

The experimental setup of this case is different from that of last section because of the addition of a second set of six IDCs to improve efficiency of dehumidified air ventilation.

TRNSYS Simulation External environmental data for 20:00 – 06:00 hours from the meteorological station were used. Other relevant data are summarized in Table 3.

Table 3 Data of the room, cooling panels, and load during 20:00 - 06:00 on 02 – 03 August 2004

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Values for 02-03 August 04</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial temperature</td>
<td>31</td>
</tr>
<tr>
<td>Flow rate of cooling water into ceiling panel (kgh\textsuperscript{-1})</td>
<td>250</td>
</tr>
<tr>
<td>Set temperature of cooling water</td>
<td>24</td>
</tr>
<tr>
<td>Load within the mosquito net</td>
<td>56.1</td>
</tr>
<tr>
<td>Radiative (W\textsubscript{rad})</td>
<td>23.9</td>
</tr>
<tr>
<td>Convective (W\textsubscript{con})</td>
<td></td>
</tr>
<tr>
<td>Values of personal variables</td>
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</tr>
<tr>
<td>Clothing insulation (clo)</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Results of Experiments and of Simulation of Radiant Cooling System As results of shielding by the net, PMV\textsubscript{m} and PMV\textsubscript{T1} were all below 0.5 for the night as seen from the graphs in Fig. 11. The use of a cool ceiling panel in the mosquito net was effective in reducing air temperature and the mean radiant temperature resulting in acceptable PMV, especially for a reclining person. Note that the thermostat cut out from 01:45 – 3:00 and 4:00 – 6:00.

For the experiment, the ventilation air was dehumidified by the solid desiccant. The total weight of dry silica gel mass in the twelve packs increased from 3656 to 4357 g. The increased weight was approximately 19.17 % (an addition of 701 g moisture) of the original dry weight. This is equivalent to a moisture adsorption rate of 5.84 gh\textsuperscript{-1} pack\textsuperscript{-1}. The adsorption rate of each IDC in this experiment with two sets is not found to be significantly different from the rate in the experiment with one set of desiccant packs. Thus, with either one or many sets of IDC, the possible moisture adsorption rates do not differ from this rate.

Fig. 12 shows the calculated adsorption rate of solid desiccant for measured values of ventilation air. These adsorption rate values for the two sets of six IDCs are nearly twice those for one set of six IDCs. At 06:00, the adsorption rate was -40 gh\textsuperscript{-1}, thus indicating that the desiccant still able to remove moisture from ventilation air.

6. CONCLUSION

This dehumidification setup was used in conjunction with a radiant panel supplied with chilled water to cool the room to achieve thermal comfort. This combination enables quiet quality thermal comfort to be achieved. The use of solid desiccant pack beds reduces moisture in the ventilation air resulting in the reduction of humidity in the room. This allows cold water at a lower temperature to be used in the radiant panel, thus increasing the capacity of the panel. At lower temperatures, the capacity for achieving thermal comfort is enhanced.

REFERENCES

ventilation and solar regenerated desiccant materials, *WREC*, 686-689


